

FORM PTO-1390 (Modified)  
(REV 11-2000)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

**TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371**

R.36081

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

**10/018681**

INTERNATIONAL APPLICATION NO.

**PCT/DE 00/01671**

INTERNATIONAL FILING DATE

**24 May 2000**

PRIORITY DATE CLAIMED

**19 June 1999**

TITLE OF INVENTION

**PIEZOELECTRIC ACTUATOR**

APPLICANT(S) FOR DO/EO/US

**STOECKLEIN, Wolfgang BOECKING, Friedrich**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a. ☒ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☒ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☒ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

**Items 13 to 20 below concern document(s) or information included:**

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

**Transmittal sheets in duplicate w/fees charged to Dep. Acct. 07-2100 - Copy of German Text Appl. w/2 sheets drawings  
Translation of German Text Appl. w/2 sheets drawings - Letter to the Official Draftsman - Preliminary Amendment  
Copy of German Text Amended Pages - Translation of German Text Amended Pages - Copy of PCT/RO/101,  
Copy of PCT/ISA/210 and 220 Copy of PCT/IPEA/409, 416 - Executed Declaration and Assignment (Not Enclosed)**



U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.101) <b>10/018681</b>	INTERNATIONAL APPLICATION NO. <b>PCT/DE 00/01671</b>	ATTORNEY'S DOCKET NUMBER <b>R.36081</b>
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24. The following fees are submitted:

**BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5) ) :**

- ☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... **\$1040.00**
- ☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... **\$890.00**
- ☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... **\$740.00**
- ☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... **\$710.00**
- ☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... **\$100.00**

**ENTER APPROPRIATE BASIC FEE AMOUNT =**

**CALCULATIONS PTO USE ONLY**

**\$890.00**

Surcharge of **\$130.00** for furnishing the oath or declaration later than ☒ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).

**\$130.00**

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	17 - 20 =	0	x \$18.00	<b>\$0.00</b>	
Independent claims	- 3 =	0	x \$84.00	<b>\$0.00</b>	
Multiple Dependent Claims (check if applicable). <input type="checkbox"/>				<b>\$0.00</b>	

**TOTAL OF ABOVE CALCULATIONS = \$1,020.00**

☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.

**\$0.00**

**SUBTOTAL = \$1,020.00**

Processing fee of **\$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).

**\$0.00**

**TOTAL NATIONAL FEE = \$1,020.00**

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable). ☐

**\$0.00**

**TOTAL FEES ENCLOSED = \$1,020.00**

Amount to be:	\$
refunded	
charged	\$

- a. ☐ A check in the amount of \_\_\_\_\_ to cover the above fees is enclosed.
- b. ☒ Please charge my Deposit Account No. **07-2100** in the amount of **\$1,020.00** to cover the above fees. A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **07-2100**. A duplicate copy of this sheet is enclosed.
- d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

**SEND ALL CORRESPONDENCE TO:**

Ronald E. Greigg  
GREIGG & GREIGG P.L.L.C.  
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Alexandria, Virginia 22314

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SIGNATURE

Ronald E. Greigg

NAME

31,517

REGISTRATION NUMBER

19 December 2001

DATE



## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Wolfgang Stoecklein et al

Based on PCT/DE 00/01671

For: Piezoelectric Actuator

**PRELIMINARY AMENDMENT**

Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Prior to examination, please amend the above-identified application as follows:

**IN THE SPECIFICATION**

**Page 1**, between the title and paragraph [0001], insert:

[0000.2] CROSS-REFERENCE TO RELATED APPLICATIONS

[0000.4] This application is a 35 USC 371 application of PCT/DE 00/01671 filed  
on May 24, 2000.

[0000.6] BACKGROUND OF THE INVENTION

replace paragraph [0001] with the following amended paragraph:

[0001] Field of the Invention

replace paragraph [0002] with the following amended paragraph:

[0002] The invention relates to a piezoelectric actuator, for instance for  
actuating a mechanical component such as a valve or the like.



after paragraph [0002] insert the following new paragraph:

[0002.5] Description of the Prior Art

replace paragraph [0004] with the following amended paragraph:

[0004] The aforementioned piezoelectric actuators are often used in the positioning of valves. Among other factors, it must be considered here that their stroke capacity for actuating a valve tappet, for instance, is relative slight for a comparatively great force. To increase the useful stroke, it is therefore known to provide a mechanical or hydraulic travel booster. Such mechanical or hydraulic travel boosting systems, however, entail greater effort and therefore greater expense as well.

**Page 2**, replace paragraph [0005] with the following amended paragraph:

[0005] SUMMARY OF THE INVENTION

**Page 5**, replace paragraph [0015] with the following amended paragraph:

[0015] These and other characteristics of preferred refinements of the invention will become apparent from the description and the drawings; the individual characteristics, each alone or a plurality of them in the form of subsidiary combinations, can be realized in the embodiment of the invention and in other fields and can represent both advantageous and intrinsically patentable embodiments for which patent protection is here claimed.

replace paragraph [0016] with the following amended paragraph:

[0016] BRIEF DESCRIPTION OF THE DRAWINGS



**Page 6**, replace paragraph [0017] with the following amended paragraph:

[0017] Exemplary embodiments of the piezoelectric actuator of the invention with a narrow design, for instance for positioning a valve, will be explained in conjunction with the drawings, in which:

**Page 7**, replace paragraph [0026] with the following amended paragraph:

[0026] DESCRIPTION OF THE PREFERRED EMBODIMENTS

replace paragraph [0027] with the following amended paragraph:

[0027] In Fig. 1, a piezoelectric actuator 1 is shown that has a piezoelectric element 2, which in a manner known per se is constructed of piezoelectric sheets of a quartz material with a suitable crystalline structure, so that by utilizing the so-called piezoelectric effect upon application of an external electrical voltage to electrodes 3 and 4, a mechanical reaction of the piezoelectric actuator 1 is effected, in the form of a useful force  $F_u$ . The exemplary embodiment in Fig. 1 is not temperature-compensated and furnishes a compressive force  $F_u$ .

**Page 8**, replace paragraph [0030] with the following amended paragraph:

[0030] A second exemplary embodiment of a piezoelectric actuator 20 is shown in Fig. 4; here, components functioning the same are identified by the same reference numerals as in Fig. 1. In the arrangement of Fig. 4, there is one piezoelectric element 21, and there are stabilizing elements 22 that are made from a ceramic material with approximately the same coefficient of temperature expansion as the piezoelectric element 21. The support plate 8 is prestressed here in the housing 10 via a spring 23; the prestressing force of the spring 23 must be



substantially greater than that of the prestressing spring 6, so that the different temperature expansions between the housing 10 and the piezoelectric element 21 can be compensated for via the spring 23. However, it is also possible to omit the spring 23. Then the piezoelectric element 21 would be held together by the upper support plate 8, analogously to what Fig. 1 shows, and optionally also by a lower support plate. The upper support plate 8 would, as in Fig. 1, rest on a shoulder of the housing 10. The spring 23 prevents the stabilizing element 22 from being subject to tensile stress that can be caused by the prestressing of the piezoelectric element. This prestressing is accomplished with the aid of the spring 6.

**Page 9**, replace paragraph [0031] with the following amended paragraph:

[0031] An actuation of the piezoelectric actuator 20, in this exemplary embodiment as well, leads to an axial expansion of the piezoelectric element 21 and thus to a compressive force  $[F_{\text{useful}}] E_u$  counter to the prestressing of the prestressing spring 6. Since here as well the piezoelectric element 21 and the stabilizing elements 22 have essentially the same coefficients of temperature expansion, the temperature-caused expansions of the piezoelectric element 21 and of the stabilizing elements 22, in the proposed mechanical mounting, cause the influences of the two elements 21 and 22 to be cancelled out in the effective direction. Thus the actuating element, connected to the spring plate 7 of the piezoelectric element 21, can remain in its position.

replace paragraph [0032] with the following amended paragraph:

[0032] A third exemplary embodiment of a piezoelectric actuator 30 is shown in Fig. 5; once again, components that function the same are provided with the same



reference numerals as in Fig. 1 or Fig. 4. In the arrangement of Fig. 5, in contrast to the disposition of Fig. 4, only a piezoelectric element 31 with longitudinally stacked piezoelectric layers is provided. An actuation of the piezoelectric actuator 30 in this exemplary embodiment leads to an axial shortening of the piezoelectric element 31 and thus to useful tensile force  $F_u$  that acts on the actuating element.

**Page 10, paragraph [0034]:**

[0034] From Fig. 8, a further exemplary embodiment of a piezoelectric actuator 40 can be seen; once again, the components functioning the same are provided with the same reference numerals as in Fig. 1, Fig. 4 or Fig. 5. In the arrangement of Fig. 8, two piezoelectric elements 41 and 42 are disposed symmetrically to a tension rod 43, which represents the actuating element. The piezoelectric elements 41 and 42 and the tension rod 43 are disposed, surrounded by the intermediate layer 11, in the housing 10 of the piezoelectric actuator 40. The piezoelectric elements 41 and 42 here are furthermore held between a support plate 44, connected to the tension rod, and via the spring 23 on an upper fixation edge in the housing 10 and a lower fixation edge in the housing 10. This arrangement furnishes a tensile force as the force  $F_u$  and is not temperature- compensated.

**Page 11, insert the following new paragraph:**

[0035] The foregoing relate to preferred exemplary embodiments of the invention, it being understood that other variants and embodiments thereof are possible within the spirit and scope of the invention, the latter being defined by the appended claims.

**Page 12, delete "New Claims 1-8" and insert --We Claim--.**



## **IN THE CLAIMS**

Please cancel claims 1-8 and add new claims 9-25.

9. A piezoelectric actuator comprising a housing (10), in which at least one piezoelectric element (2; 21; 31; 41; 42) for subjecting an actuating element to a tensile force or compressive force is disposed and is guided longitudinally movably by means of a flexible intermediate layer (11), and

stabilizing elements (9, 22), disposed parallel to this piezoelectric element (2; 21; 31; 41, 42), to prevent bending tensions in the piezoelectric element (2; 21; 31; 41; 42) said intermediate layer (11) being located between the piezoelectric element (2; 21; 31; 41; 42) and the stabilizing elements (9, 22),

the ratio of the length of the piezoelectric element (2; 21; 31; 41; 42) and the stabilizing elements (9, 22) in the effective direction (Z axis) to the width transversely to the effective direction (X, Y direction) is from 5:1 to 50:1.

10. The piezoelectric actuator of claim 9, wherein

the stabilizing elements (9) are of steel and are held between a base or support plate (8) fastened firmly in the housing (10) of the piezoelectric actuator (1) and a fixation edge in the housing (10), and wherein the piezoelectric element (2; 21; 31; 41; 42) is held between the base plate (8) and a spring plate (7) which, via a prestressing spring (6), likewise rests on the housing (10) and guides the actuating element.



11. The piezoelectric actuator of claim 9, wherein

the piezoelectric element (21; 31) and the stabilizing elements (22) are of ceramic materials, which have essentially the same coefficients of temperature expansion, and the stabilizing elements (22) are held between a base or support plate (8) and a fixation edge in the housing (10),

wherein the piezoelectric element (21; 31) is held between the base plate (8) and a spring plate (7), which via a prestressing spring (6) likewise rests on the housing (10) and guides the actuating element,

and wherein the stabilizing element (22) is coupled mechanically with the piezoelectric element (21; 31) in such a way that the temperature-dictated expansions of the piezoelectric element (21; 31) and of the stabilizing element (22) cancel one another out in the effective direction in such a way that the actuating element remains in its position.

12. The piezoelectric actuator of claim 11, wherein

the base plate (8) rests on the housing (10) via a spring (23).



13. The piezoelectric actuator of claim 10, wherein

the piezoelectric element (21) is constructed of transversely stacked piezoelectric layers and thus exerts a compressive force on the actuating element.

14. The piezoelectric actuator of claim 11, wherein

the piezoelectric element (21) is constructed of transversely stacked piezoelectric layers and thus exerts a compressive force on the actuating element.

15. The piezoelectric actuator of claim 12, wherein

the piezoelectric element (21) is constructed of transversely stacked piezoelectric layers and thus exerts a compressive force on the actuating element.

16. The piezoelectric actuator of claim 10, wherein

the piezoelectric element (21) is constructed of longitudinally stacked piezoelectric layers and thus exerts a tensile force on the actuating element.

17. The piezoelectric actuator of claim 11, wherein

the piezoelectric element (21) is constructed of longitudinally stacked piezoelectric layers and thus exerts a tensile force on the actuating element.



18. The piezoelectric actuator of claim 12, wherein

the piezoelectric element (21) is constructed of longitudinally stacked piezoelectric layers and thus exerts a tensile force on the actuating element.

19. The piezoelectric actuator of claim 13, wherein

the stabilizing elements (22) comprise piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element (21; 31), which piezoelectric layers are triggered with a voltage in the same way as the piezoelectric element (21; 31).

20. The piezoelectric actuator of claim 14, wherein

the stabilizing elements (22) comprise piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element (21; 31), which piezoelectric layers are triggered with a voltage in the same way as the piezoelectric element (21; 31).

21. The piezoelectric actuator of claim 15, wherein

the stabilizing elements (22) comprise piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element (21; 31), which



piezoelectric layers are triggered with a voltage in the same way as the piezoelectric element (21; 31).

22. The piezoelectric actuator of claim 16, wherein

the stabilizing elements (22) comprise piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element (21; 31), which piezoelectric layers are triggered with a voltage in the same way as the piezoelectric element (21; 31).

23. The piezoelectric actuator of claim 17, wherein

the stabilizing elements (22) comprise piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element (21; 31), which piezoelectric layers are triggered with a voltage in the same way as the piezoelectric element (21; 31).

24. The piezoelectric actuator of claim 18, wherein

the stabilizing elements (22) comprise piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element (21; 31), which piezoelectric layers are triggered with a voltage in the same way as the piezoelectric element (21; 31).



25. The piezoelectric actuator of claim 9, wherein

two piezoelectric elements (41, 42) are disposed symmetrically to a tension rod (43), acting as the actuating element, surrounded by the intermediate layer (41) in the housing (10) of the piezoelectric actuator (40), and wherein the piezoelectric elements (41, 42) are held between a support plate (44), connected to the tension rod (43), and a fixation edge in the housing (10), and wherein the support plate (44) rests on the housing (10) via a spring (23).



**IN THE ABSTRACT**

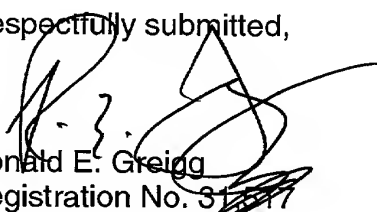
Please substitute the attached Abstract of the Disclosure for the abstract as originally as filed.

**REMARKS**

The above amendments are being made to place the application in better condition for examination.

Entry of the amendment is respectfully solicited.

Respectfully submitted,

  
Ronald E. Greigg  
Registration No. 31577  
Attorney for Applicants  
Customer No. 002119

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Page 16, replace the abstract for the following amended abstract:

Abstract of the Disclosure

A piezoelectric actuator in which at least one piezoelectric element is present for subjected an actuating element to a tensile force or compressive force. In addition, stabilizing elements are mounted parallel to the piezoelectric element with a flexible intermediate layer located between the elements. The piezoelectric element and the stabilizing elements have a great length in the effective direction (Z axis) in proportion to their width transversely to the effective direction (X, Y direction).



**VERSION WITH MARKINGS TO SHOW CHANGES MADE**

**Page 1**, paragraphs [0000.2] through [0004]:

[0000.2] CROSS-REFERENCE TO RELATED APPLICATIONS

[0000.4] This application is a 35 USC 371 application of PCT/DE 00/01671 filed on May 24, 2000.

[0000.6] BACKGROUND OF THE INVENTION

[0001] [Prior Art] Field of the Invention

[0002] The invention relates to a piezoelectric actuator, for instance for actuating a mechanical component such as a valve or the like[, in accordance with the generic characteristics of the preamble to the main claim].

[0002.5] Description of the Prior Art

[0004] The aforementioned piezoelectric actuators are often used in the positioning of valves. Among other factors, it must be considered here that their stroke capacity for actuating a valve tappet, for instance, is relative slight for a comparatively great force. To increase the useful stroke, it is therefore [sometimes usual] known to provide a mechanical or hydraulic travel booster. Such mechanical or hydraulic travel boosting systems, however, entail greater effort and therefore greater expense as well.



**Page 2**, paragraph [0005]:

[0005] [Advantage of the Invention] SUMMARY OF THE INVENTION

**Page 5**, paragraph [0015] and [0016]:

[0015] These and other characteristics of preferred refinements of the invention will become apparent from [the claims and] the description and the drawings; the individual characteristics, each alone or a plurality of them in the form of subsidiary combinations, can be realized in the embodiment of the invention and in other fields and can represent both advantageous and intrinsically patentable embodiments for which patent protection is here claimed.

[0016] [Drawing] BRIEF DESCRIPTION OF THE DRAWINGS

**Page 6**, paragraph [0017]:

[0017] Exemplary embodiments of the piezoelectric actuator of the invention with a narrow design, for instance for positioning a valve, will be explained in conjunction with the [drawing. Shown are] drawings, in which:

**Page 7**, paragraph [0026] and [0027]:

[0026] [Description of the Exemplary Embodiments] DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] In Fig. 1, a piezoelectric actuator 1 is shown that has a piezoelectric element 2, which in a manner known per se is constructed of piezoelectric sheets of



a quartz material with a suitable crystalline structure, so that by utilizing the so-called piezoelectric effect upon application of an external electrical voltage to electrodes 3 and 4, a mechanical reaction of the piezoelectric actuator 1 is effected, in the form of a useful force  $[E_{\text{useful}}] E_u$ . The exemplary embodiment in Fig. 1 is not temperature-compensated and furnishes a compressive force  $[E_{\text{useful}}] E_u$ .

**Page 8, paragraph [0030]:**

[0030] A second exemplary embodiment of a piezoelectric actuator 20 is shown in Fig. 4; here, components functioning the same are identified by the same reference numerals as in Fig. 1. In the arrangement of Fig. 4, there is one piezoelectric element 21, and there are stabilizing elements 22 that are made from a ceramic material with approximately the same coefficient of temperature expansion as the piezoelectric element 21. The support plate 8 is prestressed here in the housing 10 via a spring 23; the prestressing force of the spring 23 must be substantially greater than that of the prestressing spring 6, so that the different temperature expansions between the housing 10 and the piezoelectric element 21 can be compensated for via the spring 23. However, it is also possible to omit the spring 23. Then the piezoelectric element 21 would be held together by the upper support plate 8, analogously to what Fig. 1 shows, and optionally also by a lower support plate. The upper support plate 8 would, as in Fig. 1, rest on a shoulder of the housing 10. The spring 23 prevents the stabilizing element 22 from being subject to tensile stress that can be caused by the prestressing of the piezoelectric element. This prestressing is accomplished with the aid of the spring 6.



**Page 9, paragraph [0031]:**

[0031] An actuation of the piezoelectric actuator 20, in this exemplary embodiment as well, leads to an axial expansion of the piezoelectric element 21 and thus to a compressive force  $[F_{\text{useful}}] E_u$  counter to the prestressing of the prestressing spring 6. Since here as well the piezoelectric element 21 and the stabilizing elements 22 have essentially the same coefficients of temperature expansion, the temperature-caused expansions of the piezoelectric element 21 and of the stabilizing [element] elements 22, in the proposed mechanical mounting, cause the influences of the two elements 21 and 22 to be cancelled out in the effective direction. Thus the actuating element, connected to the spring plate 7 of the piezoelectric element 21, can remain in its position.

[0032] A third exemplary embodiment of a piezoelectric actuator 30 is shown in Fig. 5; once again, components that function the same are provided with the same reference numerals as in Fig. 1 or Fig. 4. In the arrangement of Fig. 5, in contrast to the disposition of Fig. 4, only [one] a piezoelectric element 31 [is provided] with longitudinally stacked piezoelectric layers is provided. An actuation of the piezoelectric actuator 30 in this exemplary embodiment leads to an axial shortening of the piezoelectric element 31 and thus to useful tensile force  $[F_{\text{useful}}] E_u$  that acts on the actuating element.

**Page 10, paragraph [0034]:**

[0034] From Fig. 8, a further exemplary embodiment of a piezoelectric actuator 40 can be seen; once again, the components functioning the same are



provided with the same reference numerals as in Fig. 1, Fig. 4 or Fig. 5. In the arrangement of Fig. 8, two piezoelectric elements 41 and 42 are disposed symmetrically to a tension rod 43, which represents the actuating element. The piezoelectric elements 41 and 42 and the tension rod 43 are disposed, surrounded by the intermediate layer 11, in the housing 10 of the piezoelectric actuator 40. The piezoelectric elements 41 and 42 here are furthermore held between a support plate 44, connected to the tension rod, and via the spring 23 on an upper fixation edge in the housing 10 and a lower fixation edge in the housing 10. This arrangement furnishes a tensile force as the force  $[F_{\text{useful}}] E_u$  and is not temperature-compensated.

**Page 11**, paragraph [0035]:

[0035]      The foregoing relate to preferred exemplary embodiments of the invention, it being understood that other variants and embodiments thereof are possible within the spirit and scope of the invention, the latter being defined by the appended claims.



Abstract of the Disclosure

A piezoelectric actuator [is proposed,] in which at least one piezoelectric element [(2; 21; 31; 41, 42)] is present[,] for subjecting an actuating element to a tensile force or compressive force. In addition, stabilizing elements [(9; 22)] are  
5 [provided, which] mounted parallel to the piezoelectric element [(2; 21; 31; 41, 42)] with a flexible intermediate layer [(11)] located between the elements. The piezoelectric element [(2; 21; 31; 41, 42)] and the stabilizing elements [(9; 22)] have a great length in the effective direction (Z axis) in proportion to their width transversely to the effective direction (X, Y direction).

10 [(Fig. 1)]



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Wolfgang Stoecklein et al

Based on PCT/DE 00/01671

For: Piezoelectric Actuator

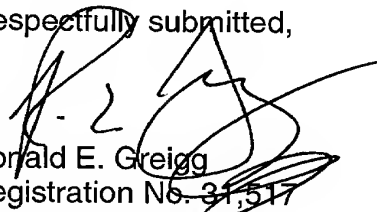
**LETTER TO THE OFFICIAL DRAFTSMAN**

Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Please find attached two sheets of drawings with corrections as marked in red.

Respectfully submitted,

  
Ronald E. Greigg  
Registration No. 31,517  
Attorney for Applicants  
Customer No. 002119

Greigg & Greigg P.L.L.C.  
1423 Powhatan Street  
Unit One  
Alexandria, Virginia 22314

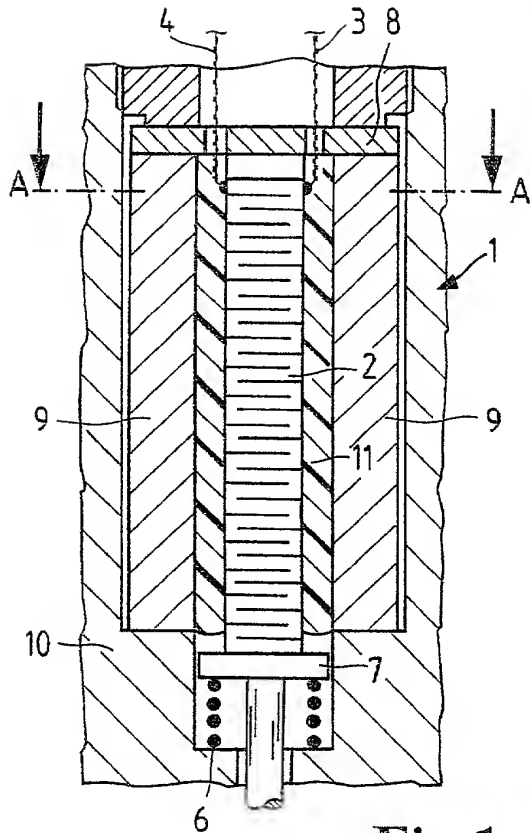
Telephone: 703-838-5500  
Facsimile: 703-838-5554

Date: December 19, 2001

10018681-040201

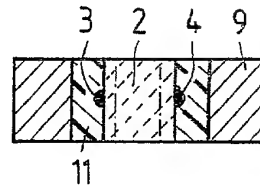
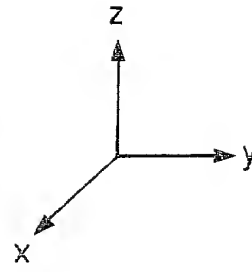


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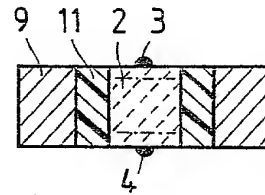


**Fig.1**

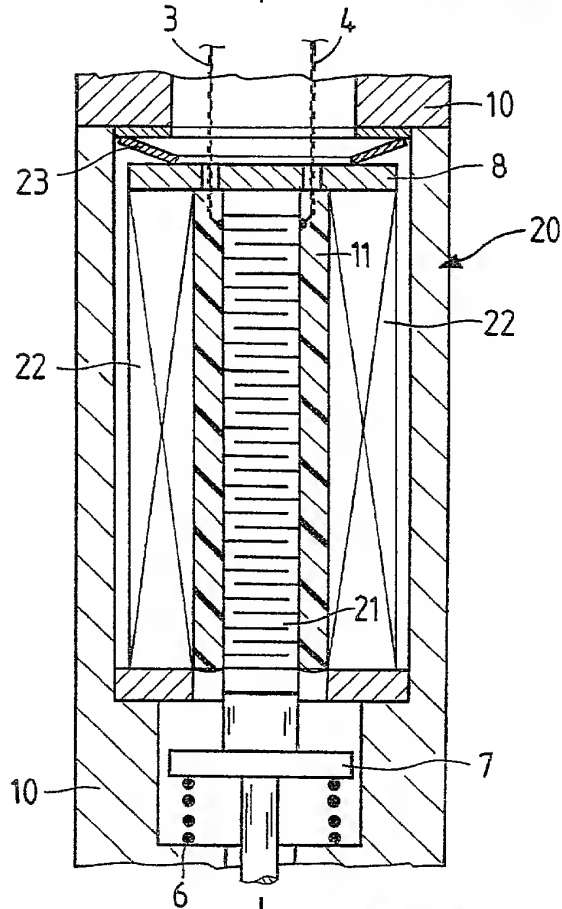
$F_{\text{Nutz}}$   $F_u$   
 ~~$F_{\text{Nutz}}$~~



**Fig.2**



**Fig. 3**



**Fig.4**

$F_{\text{Nutz}}$   $F_u$   
 ~~$F_{\text{Nutz}}$~~



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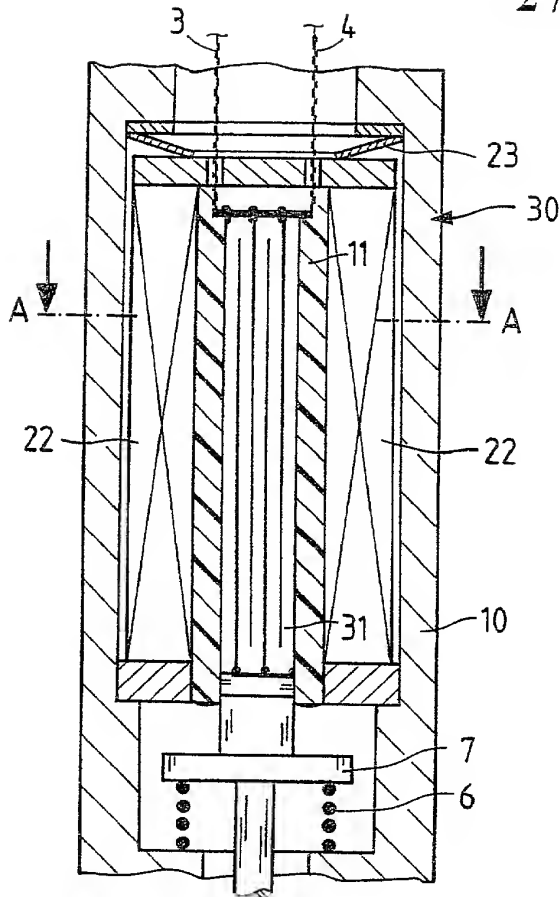


Fig. 5

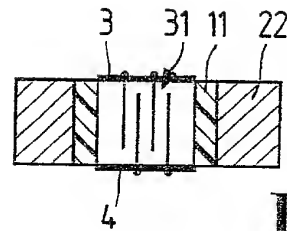


Fig. 6

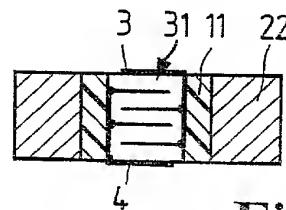


Fig. 7

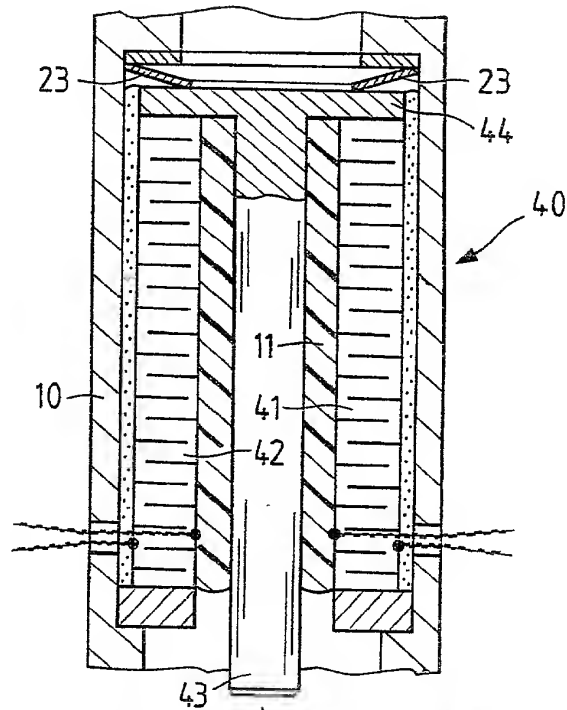
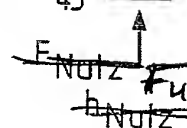


Fig. 8





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531 Rec'd PCT/TT 19 DEC 2001

PIEZOELECTRIC ACTUATOR

[0001] Prior Art

[0002] The invention relates to a piezoelectric actuator, for instance for actuating a mechanical component such as a valve or the like, in accordance with the generic characteristics of the preamble to the main claim.

[0003] It is widely known that by utilizing the so-called piezoelectric effect, a piezoelectric element can be constructed from a material with a suitable crystalline structure. When an external electrical voltage is applied, a mechanical reaction of the piezoelectric element takes place, which depending on the crystalline structure and the regions where the electrical voltage is applied causes a compression or tension in a predeterminable direction.

[0004] The aforementioned piezoelectric actuators are often used in the positioning of valves. Among other factors, it must be considered here that their stroke capacity for actuating a valve tappet, for instance, is relative slight for a comparatively great force. To increase the useful stroke, it is therefore sometimes usual to provide a mechanical or hydraulic travel booster. Such mechanical or hydraulic travel boosting systems, however, entail greater effort and therefore greater expense as well.



[0005] Advantages of the Invention

[0006] The piezoelectric actuator described at the outset advantageously has at least one piezoelectric element, which is suitable for imposing a tensile force or compressive force on an actuating element. According to the invention, stabilizing elements are provided, which are disposed parallel to the piezoelectric element with a flexible intermediate layer located between the elements, wherein the piezoelectric element and the stabilizing elements have a great length in the effective direction (Z axis) in proportion to their width transversely to the effective direction (X, Y direction). An advantageous order of magnitude would for instance be a ratio of length (Z direction) to width (X, Y direction) is approximately 5:1 to 50:1.

[0007] In a first advantageous embodiment, the stabilizing elements are of steel and are held between a base or support plate fastened firmly in the housing of the piezoelectric actuator and a fixation edge in the housing. The housing here is as a rule also made from steel. The piezoelectric element is held between the base plate and a spring plate which, via a prestressing spring, likewise rests on the housing and guides the actuating element.

[0008] With the invention, a long, narrow piezoelectric actuator is created in a simple way that is mechanically relatively invulnerable, for instance to vibration when used



in the engine compartment of a motor vehicle. Because of the long stroke resulting from the long, narrow design, a stroke boost can be dispensed with, and in principle, tensile forces or compressive forces can be generated by the piezoelectric actuator.

[0009] Because a flexible intermediate layer, for instance of plastic such as a polymer or the like, is mounted between the stabilizing elements and the piezoelectric element, a longitudinal motion, which represents a relative motion between the piezoelectric element and the stabilizing element, can be allowed. An oscillating motion of the piezoelectric element in the X or Y direction can be avoided, however. It is thus possible in a simple way to prevent bending tensions in the piezoelectric element that could possibly lead to the destruction of the piezoelectric actuator.

[0010] The aforementioned concrete embodiment furnishes downward-oriented compressive forces and is not temperature-compensated. In a second embodiment, the piezoelectric element and the stabilizing elements are of ceramic materials, which have essentially the same coefficients of temperature expansion, so that this embodiment is temperature-compensated. The stabilizing element is here as well held between a base plate and a fixation edge in the housing, but the base plate rests on the housing via a spring.



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[0011] In this last embodiment, the stabilizing element is mechanically coupled to the piezoelectric element in such a way that the temperature-dictated expansions of the piezoelectric element and of the stabilizing elements cancel one another out in the effective direction in such a way that the actuating element remains in its position, or in other words no zero-point drift occurs. The piezoelectric element is held between the base plate and a spring plate, which via a prestressing spring likewise rests on the housing and guides the actuating element. Here the force of the prestressing spring must be substantially greater than that of the spring on the base plate, so that the different temperature expansions between the housing and the material comprising the piezoelectric element are compensated for via the spring. Additional provisions for temperature compensation, as was often provided until now by hydraulic coupling, are no longer necessary here.

[0012] In the invention, the piezoelectric element can be constructed of transversely stacked piezoelectric layers and thus exerts a compressive force on the actuating element, or of longitudinally stacked piezoelectric layers and thus exerts a tensile force on the actuating element.

[0013] In other advantageous embodiments, the stabilizing element comprises piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element, which piezoelectric layers are triggered with a



voltage in the same way as the piezoelectric element. With this embodiment, in addition to the temperature compensation, the useful stroke is also lengthened by means of the additional stroke of the stabilizing elements. The contacting of the piezoelectric layers can be located in the intermediate layer or outside it.

[0014] In another advantageous embodiment of the invention, two piezoelectric elements are disposed symmetrically to a tension rod, acting as the actuating element, surrounded by the intermediate layer in the housing of the piezoelectric actuator. The piezoelectric elements here are held between a support plate, connected to the tension rod, and a fixation edge in the housing, and the support plate rests on the housing via a spring.

[0015] These and other characteristics of preferred refinements of the invention will become apparent from the claims and the description and the drawings; the individual characteristics, each alone or a plurality of them in the form of subsidiary combinations, can be realized in the embodiment of the invention and in other fields and can represent both advantageous and intrinsically patentable embodiments for which patent protection is here claimed.

[0016] Drawing



[0017] Exemplary embodiments of the piezoelectric actuator of the invention with a narrow design, for instance for positioning a valve, will be explained in conjunction with the drawing. Shown are:

[0018] Fig. 1, a section through a non-temperature-compensated piezoelectric actuator with steel stabilizing elements;

[0019] Fig. 2, a detail taken along a section line A-A of Fig. 1, with a first contacting option for the piezoelectric element;

[0020] Fig. 3, a detail taken along a section line A-A of Fig. 1, with a second contacting option for the piezoelectric element;

[0021] Fig. 4, a section through a temperature-compensated, transversely stacked piezoelectric element of the piezoelectric actuator, with a ceramic stabilizing element;

[0022] Fig. 5, a section through a temperature-compensated, longitudinally stacked piezoelectric element of the piezoelectric actuator, with a ceramic stabilizing element;

[0023] Fig. 6, a detail taken along a section line A-A of Fig. 5, with a first contacting option for the piezoelectric element;



[0024] Fig. 7, a detail taken along a section line A-A of Fig. 5, with a second contacting option for the piezoelectric element; and

[0025] Fig. 8, a section through a non-temperature-compensated piezoelectric actuator with two piezoelectric elements disposed one on either side of a tension rod.

[0026] Description of the Exemplary Embodiments

[0027] In Fig. 1, a piezoelectric actuator 1 is shown that has a piezoelectric element 2, which in a manner known per se is constructed of piezoelectric sheets of a quartz material with a suitable crystalline structure, so that by utilizing the so-called piezoelectric effect upon application of an external electrical voltage to electrodes 3 and 4, a mechanical reaction of the piezoelectric actuator 1 is effected, in the form of a force  $F_{\text{useful}}$ . The exemplary embodiment in Fig. 1 is not temperature-compensated and furnishes a compressive force  $F_{\text{useful}}$ .

[0028] The relatively long, slender piezoelectric element 2 is pressed by its upper end against a base or support plate 8 by means of a prestressing spring 6 and a spring plate 7, disposed above this spring, on the lower end of the piezoelectric element. The support plate 8 is braced with stabilizing elements 9, disposed symmetrically on both sides of the piezoelectric element 2, which are braced at the top



and bottom on the housing 10 of the piezoelectric actuator 1. Between the stabilizing elements 9 and the piezoelectric element 2 is a flexible plastic, such as a polymer, located longitudinally in the form of an intermediate layer 11. The task of the flexible intermediate layer 11 is to allow a longitudinal motion, that is, the relative motion between the piezoelectric element 2 and the stabilizing elements 9, but to prevent an oscillating motion of the piezoelectric element in the X or Y direction.

[0029] From Figs. 2 and 3, possibilities for a connection of the contacts 3 and 4 of the piezoelectric element 2 are suggested; these can be effected in either the X or Y direction and can thus be located either in the intermediate layer 11 or outside it.

[0030] A second exemplary embodiment of a piezoelectric actuator 20 is shown in Fig. 4; here, components functioning the same are identified by the same reference numerals as in Fig. 1. In the arrangement of Fig. 4, there is one piezoelectric element 21, and there are stabilizing elements 22 that are made from a ceramic material with approximately the same coefficient of temperature expansion as the piezoelectric element 21. The support plate 8 is prestressed here in the housing 10 via a spring 23; the prestressing force of the spring 23 must be substantially greater than that of the prestressing spring 6, so that the different temperature expansions between the housing 10 and the piezoelectric



element 21 can be compensated for via the spring 23. However, it is also possible to omit the spring 23. Then the piezoelectric element 21 would be held together by the upper support plate 8, analogously to what Fig. 1 shows, and optionally also by a lower support plate. The upper support plate 8 would, as in Fig. 1, rest on a shoulder of the housing 10. The spring 23 prevents the stabilizing element 22 from being subject to tensile stress that can be caused by the prestressing of the piezoelectric element. This prestressing is accomplished with the aid of the spring 6.

[0031] An actuation of the piezoelectric actuator 20, in this exemplary embodiment as well, leads to an axial expansion of the piezoelectric element 21 and thus to a compressive force  $F_{\text{useful}}$ , counter to the prestressing of the prestressing spring 6. Since here as well the piezoelectric element 21 and the stabilizing elements 22 have essentially the same coefficients of temperature expansion, the temperature-caused expansions of the piezoelectric element 21 and of the stabilizing element 22, in the proposed mechanical mounting, cause the influences of the two elements 21 and 22 to be cancelled out in the effective direction. Thus the actuating element, connected to the spring plate 7 of the piezoelectric element 21, can remain in its position.

[0032] A third exemplary embodiment of a piezoelectric actuator 30 is shown in Fig. 5; once again, components that function the same are provided with the same reference



numerals as in Fig. 1 or Fig. 4. In the arrangement of Fig. 5, in contrast to the disposition of Fig. 4, only one piezoelectric element 31 is provided with longitudinally stacked piezoelectric layers. An actuation of the piezoelectric actuator 30 in this exemplary embodiment leads to an axial shortening of the piezoelectric element 31 and thus to tensile force  $F_{\text{useful}}$  that acts on the actuating element.

[0033] In Figs. 6 and 7, once again possibilities for a connection of the contacts 3 and 4 of the piezoelectric element 31 are suggested; these can again be effected with suitably oriented piezoelectric layers in either the X or Y direction and can thus be located either in the intermediate layer 11 or outside it.

[0034] From Fig. 8, a further exemplary embodiment of a piezoelectric actuator 40 can be seen; once again, the components functioning the same are provided with the same reference numerals as in Fig. 1, Fig. 4 or Fig. 5. In the arrangement of Fig. 8, two piezoelectric elements 41 and 42 are disposed symmetrically to a tension rod 43, which represents the actuating element. The piezoelectric elements 41 and 42 and the tension rod 43 are disposed, surrounded by the intermediate layer 11, in the housing 10 of the piezoelectric actuator 40. The piezoelectric elements 41 and 42 here are furthermore held between a support plate 44, connected to the tension rod, and via the spring 23 on an upper fixation edge in the housing 10 and a lower fixation



edge in the housing 10. This arrangement furnishes a tensile force as the force  $F_{\text{useful}}$  and is not temperature- compensated.



New Claims 1-8

1. A piezoelectric actuator having a housing (10), in which at least one piezoelectric element (2; 21; 31; 41; 42) for subjecting an actuating element to a tensile force or compressive force is disposed and is guided longitudinally movably by means of a flexible intermediate layer (11), characterized by

stabilizing elements (9, 22), which to prevent bending tensions in the piezoelectric element (2; 21; 31; 41; 42) are disposed parallel to this piezoelectric element (2; 21; 31; 41, 42), and the intermediate layer (11) is located between the piezoelectric element (2; 21; 31; 41; 42) and the stabilizing elements (9, 22), and the ratio of the length of the piezoelectric element (2; 21; 31; 41; 42) and the stabilizing elements (9, 22) in the effective direction (Z axis) to the width transversely to the effective direction (X, Y direction) is from 5:1 to 50:1.

2. The piezoelectric actuator of claim 1, characterized in that

the stabilizing elements (9) are of steel and are held between a base or support plate (8) fastened firmly in the



housing (10) of the piezoelectric actuator (1) and a fixation edge in the housing (10), and that the piezoelectric element (2; 21; 31; 41; 42) is held between the base plate (8) and a spring plate (7) which, via a prestressing spring (6), likewise rests on the housing (10) and guides the actuating element.

3. The piezoelectric actuator of claim 1, characterized in that

the piezoelectric element (21; 31) and the stabilizing elements (22) are of ceramic materials, which have essentially the same coefficients of temperature expansion, and the stabilizing elements (22) are held between a base or support plate (8) and a fixation edge in the housing (10),

that the piezoelectric element (21; 31) is held between the base plate (8) and a spring plate (7), which via a prestressing spring (6) likewise rests on the housing (10) and guides the actuating element,

and the stabilizing element (22) is coupled mechanically with the piezoelectric element (21; 31) in such a way that the temperature-dictated expansions of the piezoelectric element (21; 31) and of the stabilizing element (22) cancel one another out in the effective direction in such a way that the actuating element remains in its position.



4. The piezoelectric actuator of claim 3, characterized in that

the base plate (8) rests on the housing (10) via a spring (23).

5. The piezoelectric actuator of claim 2, 3 or 4, characterized in that

the piezoelectric element (21) is constructed of transversely stacked piezoelectric layers and thus exerts a compressive force on the actuating element.

6. The piezoelectric actuator of claim 2, 3 or 4, characterized in that

the piezoelectric element (21) is constructed of longitudinally stacked piezoelectric layers and thus exerts a tensile force on the actuating element.

7. The piezoelectric actuator of claim 5 or 6, characterized in that

the stabilizing elements (22) comprise piezoelectric layers, each located perpendicular to the layered structure of the piezoelectric element (21; 31), which piezoelectric layers are triggered with a voltage in the same way as the piezoelectric element (21; 31).



8. The piezoelectric actuator of claim 1, characterized in that

two piezoelectric elements (41, 42) are disposed symmetrically to a tension rod (43), acting as the actuating element, surrounded by the intermediate layer (41) in the housing (10) of the piezoelectric actuator (40), and the piezoelectric elements (41, 42) are held between a support plate (44), connected to the tension rod (43), and a fixation edge in the housing (10), and the support plate (44) rests on the housing (10) via a spring (23).



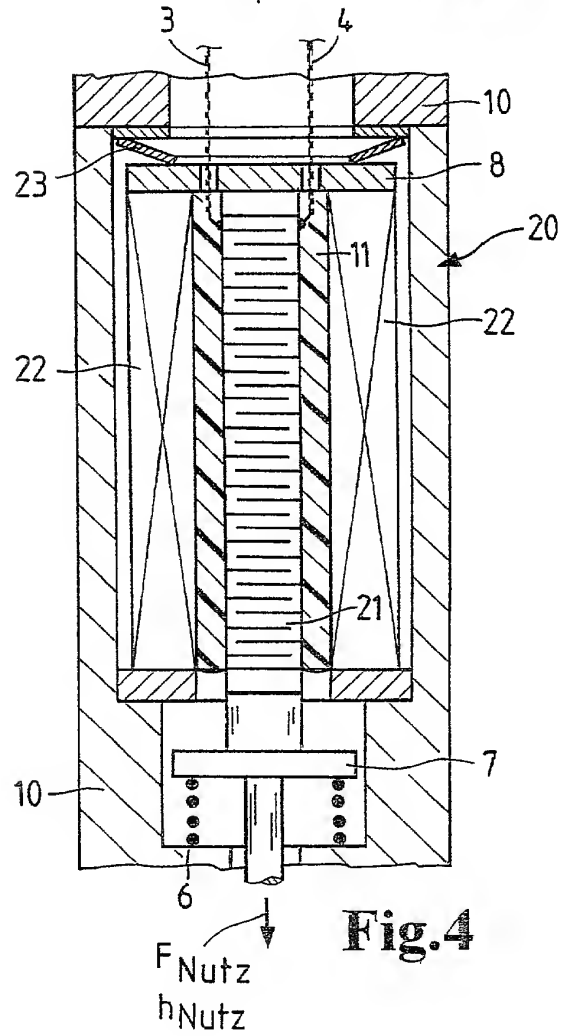
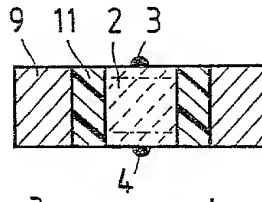
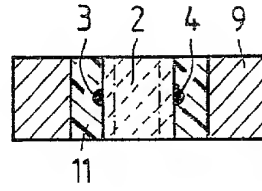
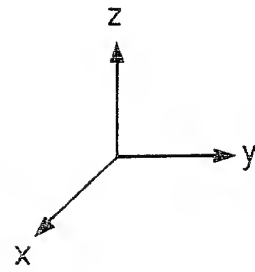
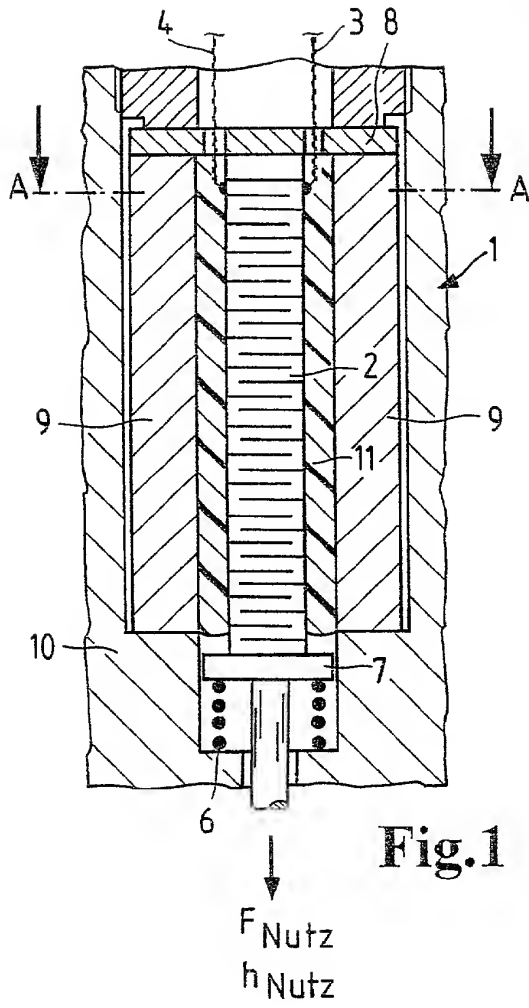
### Abstract

A piezoelectric actuator is proposed, in which at least one piezoelectric element (2; 21; 31; 41, 42) is present, for subjected an actuating element to a tensile force or compressive force. In addition, stabilizing elements (9; 22) are provided, which mounted parallel to the piezoelectric element (2; 21; 31; 41, 42) with a flexible intermediate layer (11) located between the elements. The piezoelectric element (2; 21; 31; 41, 42) and the stabilizing elements (9; 22) have a great length in the effective direction (Z axis) in proportion to their width transversely to the effective direction (X, Y direction).

(Fig. 1)

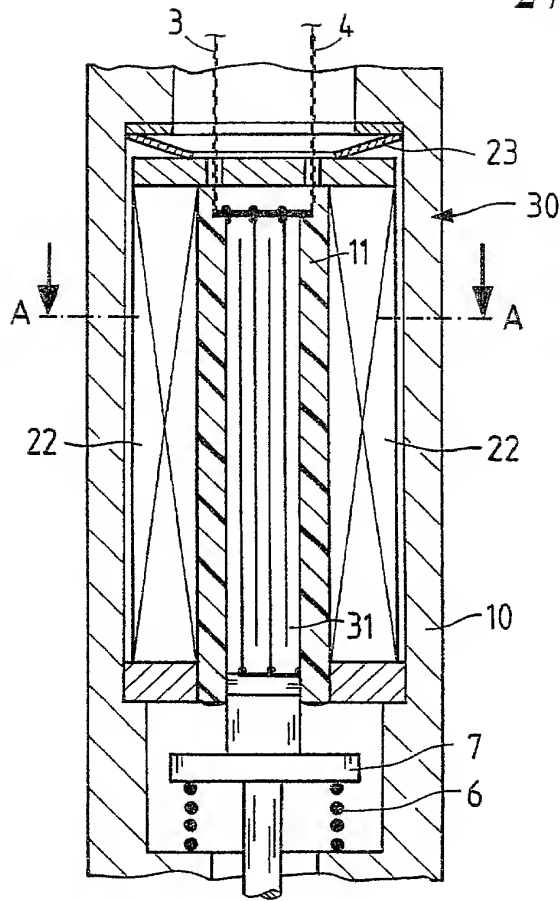


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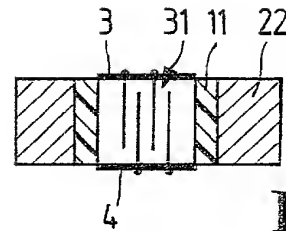


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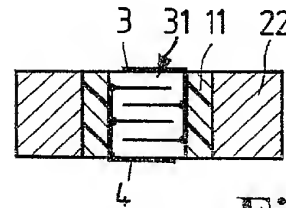


**Fig. 5**

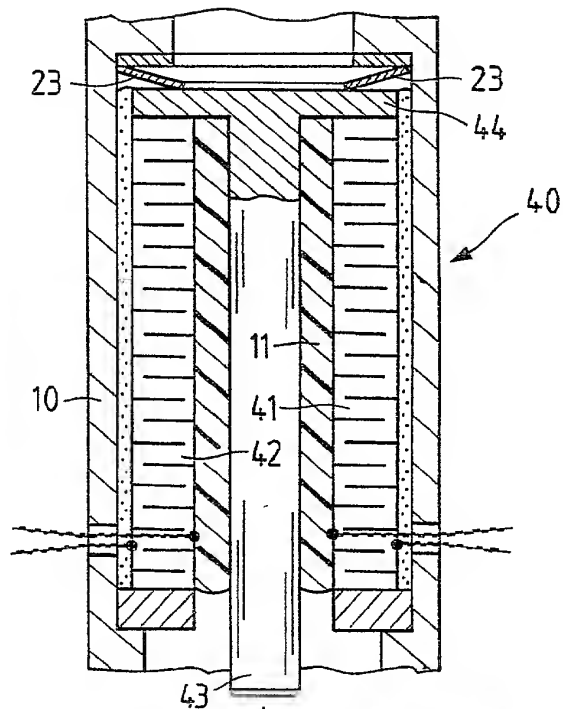
$F_{\text{Nutz}}$   
 $h_{\text{Nutz}}$



**Fig. 6**



**Fig. 7**



**Fig. 8**

$F_{\text{Nutz}}$   
 $h_{\text{Nutz}}$



Docket No.

R.36081

# Declaration and Power of Attorney For Patent Application

## English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

**PIEZOELECTRIC ACTUATOR**

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on 24 May 2000 as United States Application No. or PCT International Application Number PCT/DE 00/01671 and was amended on \_\_\_\_\_

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)	Priority	Claimed
<u>1 99 28 185.8</u> (Number)	<u>Germany</u> (Country)	<u>19 June 1999</u> (Day/Month/Year Filed)
		<input checked="" type="checkbox"/>
<u></u> (Number)	<u></u> (Country)	<u></u> (Day/Month/Year Filed)
		<input type="checkbox"/>
<u></u> (Number)	<u></u> (Country)	<u></u> (Day/Month/Year Filed)
		<input type="checkbox"/>

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I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

\_\_\_\_\_  
(Application Serial No.)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Application Serial No.)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Application Serial No.)

\_\_\_\_\_  
(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

\_\_\_\_\_  
(Application Serial No.)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Status)  
(patented, pending, abandoned)

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(Application Serial No.)

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(patented, pending, abandoned)

\_\_\_\_\_  
(Application Serial No.)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Status)  
(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.



POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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